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**4.2 W Cr²⁺:ZnSe FACE COOLED DISK
LASER**

Jason B. McKay, Won B. Roh, and Kenneth L. Schepler



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4.2 W Cr²⁺:ZnSe Face Cooled Disk Laser

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Abstract: We report a 10-kHz Cr²⁺:ZnSe laser using the face-cooled disk approach which produced 4.27 W at 2.5 μ m with 47% optical efficiency when pumped by a Q-switched Tm,Ho:YLF laser.

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1. Introduction

The Cr²⁺ laser is a promising candidate for tunable mid-IR applications. However, thermal effects have prevented the typical end-pumped, side-cooled rod laser design from producing more than 2 watts in output power[1, 2]. A resonator designed for maximum suppression of thermal effects is required for further power scaling. An attractive approach for power scaling the Cr²⁺ laser is the face-cooled disk laser design used to demonstrate high-power (>100 W) Yb lasers[3, 4]. Although intended for high-power lasers, this approach easily lends itself to power scaling the Cr²⁺ laser at more modest power levels. This paper reports demonstration of 4.27 W output from a face-cooled Cr²⁺:ZnSe disk laser.

2. Face Cooled Disk Laser

The face cooled disk is essentially a longitudinally pumped active medium, which is also cooled longitudinally through its polished faces. By using a pumped spot larger in diameter than the disk thickness, the pump-induced heat is primarily extracted longitudinally. This design therefore reduces radial thermal gradients in the active medium, thus reducing thermal lensing effects.

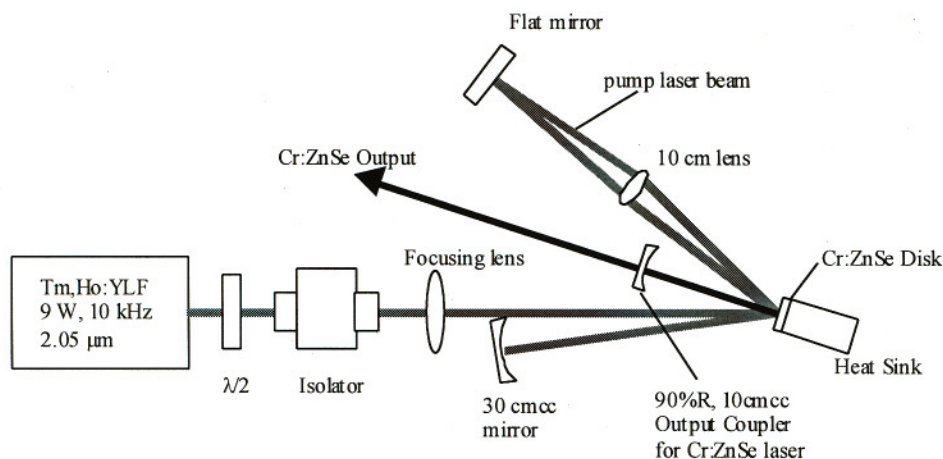


Figure 1. Cr²⁺:ZnSe Disk Laser Setup

The $\text{Cr}^{2+}:\text{ZnSe}$ disk laser, shown in Fig. 1, consisted of a pump laser, the $\text{Cr}^{2+}:\text{ZnSe}$ disk, an output coupler, and multi-pass pumping optics. The pump laser, which was a Q-switched $\text{Tm,Ho}:\text{YLF}$ laser with 9 W average power at 2.05 μm , 10-kHz pulse repetition rate, was focused to a radius of 0.5 mm at the disk. The $\text{Cr}^{2+}:\text{ZnSe}$ disk was 1 mm thick and doped to $2.3 \times 10^{19} \text{ cm}^{-3}$ Cr^{2+} concentration. The disk was AR coated on one face and HR coated on the other face for both pump and Cr^{2+} laser wavelengths. The HR coated face was soldered to a water-cooled heat sink. The output coupler was a 90% reflecting, 10-cm concave radius of curvature mirror placed 8 cm from the surface of the disk. Multi-pass pumping optics consisted of a 10-cm focal length lens, a flat mirror, and a 30-cm concave radius of curvature mirror that were used to image the pump laser back onto the disk with unity magnification four times to yield eight one-way passes. Eight-pass pumping provided 95% pump light absorption. The pump beam was aligned off axis to eliminate the need for dichroic mirrors in the resonator and produced an elliptical [2 mm x 1 mm] gain region.

The $\text{Cr}^{2+}:\text{ZnSe}$ laser produced up to 4.27 W of output with 9 W input (see Fig. 2). Threshold was 610 mW (61 $\mu\text{J/pulse}$), and slope efficiency was 50% with respect to incident pump power. Overall optical efficiency at full power was 47%. This Cr^{2+} laser was stable and ran for over six hours with less than 2% variation in average output power. This configuration showed no sign of efficiency rolloff at higher pump power, the typical effect of thermal lensing. A smaller pump beam diameter led to increased radial thermal gradients and thus thermal instability. Thus the ~1-mm diameter incident pump spot size represents the smallest useful pump spot size with respect to the 1-mm thick disk for this system.

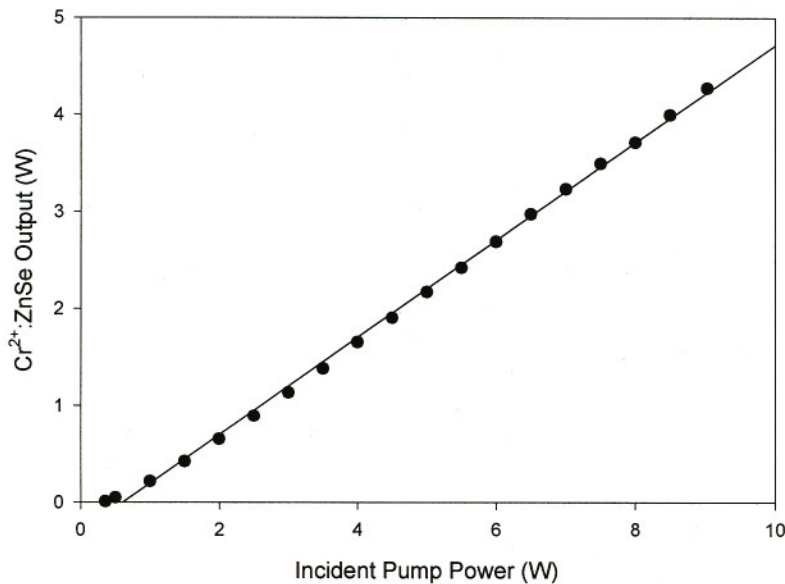


Figure 2. $\text{Cr}^{2+}:\text{ZnSe}$ Laser Performance

The Cr^{2+} output beam was elliptical in shape with divergence that was 3 and 6 times diffraction limited along the minor and major beam axes, respectively. Output beam quality did not significantly change as a function of pump power. Laser bandwidth at full power was 56 nm FWHM – typical for a free-running pulsed Cr^{2+} laser with broadband mirrors. Output pulse width was 220 ns, consisting of several short gain-switched pulses followed by a longer pulse which lasted for the duration of the remainder of the 290-ns FWHM pump pulse.

This resonator configuration did not allow for CW Cr^{2+} laser operation. Cr^{2+} laser threshold for CW pumping is expected to be on the order of 16 W for a 1-mm beam diameter. This is more power than is available from our $\text{Tm,Ho}:\text{YLF}$ pump laser. Continuous wave operation with 9 W pump power would require a smaller beam diameter and thus thinner disks.

3. Summary

We have shown that the face-cooled disk laser can effectively reduce thermal effects in Cr^{2+} lasers by demonstrating a 4.2-W, $\text{Cr}^{2+}:\text{ZnSe}$, face-cooled disk laser with output power limited only by the available pump power. The difficulty of compensating for thermal lensing inside a resonator is traded for the less difficult task of efficiently absorbing the pump laser in a thin laser crystal. For this demonstration, efficient absorption of the 2.05- μm pump power required a 1-mm thick disk, which required pulsed operation and resulted in multi-mode output given the available optics. We intend to achieve better performance in the future by using thinner disks, which should allow a smaller pump beam diameter to be used, improving beam quality and enabling CW operation. To maximize pump absorption in the thinner disks, higher Cr^{2+} doping density, additional pumping passes, and pumping at wavelengths closer to the Cr^{2+} absorption peak will be used.

4. References

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